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(54) **Projection exposure apparatus with an aberration compensation device of a projection lens**

Projektionsbelichtungsapparat mit einer Vorrichtung zur Ausgleichung der Verzeichnung einer Projektionslinse

Appareil d'exposition par projection avec un dispositif pour compenser l'aberration d'une lentille de projection

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Description

The present invention relates to a projection exposure apparatus and method, and particularly, to an exposure apparatus in which adverse influences of aberrations of a projection lens such as a symmetrical distortion, a curvature of field and the like of the projection lens to a high resolution are reduced or eliminated.

In recent years, a projection type exposure apparatus has been widely used as an apparatus for producing semiconductor integrated circuits in order to obtain higher resolution, higher exposure accuracy and greater throughput.

In the projection exposure apparatus, there is provided a projection lens between a reticle (an original plate) and a silicon wafer (a substrate), and a circuit pattern formed on the reticle is imaged on the silicon wafer with a predetermined reduction ratio or reduced magnification (normally 1/5 or 1/10) through the projection lens. Thus, a pattern image which is a reduced image of the circuit pattern is formed on the silicon wafer. In a reduction projection type exposure apparatus, a step-and-repeat exposure system is generally adopted in which a silicon wafer is shifted each time one exposure has been completed and plural pattern images are arranged over an entire silicon wafer without any clearance by plural exposures, rather than one-shot exposure system in which a pattern image is formed over an entire silicon wafer by a single exposure.

However, in order to cope with a further higher integration of a semiconductor integrated circuit, a limit to resolution which accurs in only using a reduction projection exposure apparatus to project a circuit pattern at a reduced ratio should be solved. So, it is required that the wavelength of an exposure light be made shorter and that an NA of a projection lens be made larger to improve the resolution. In this case, however, the following problems in turn arise due to a reduction of depth of focus resulting from the enlarged NA of a projection lens and due to a greater accuracy in alignment between a reticle and a silicon wafer resulting from a refined circuit pattem.

(1) Shift of a focal point of a projection lens:

The shift occurs because the projection lens absorbs part of exposure light, and the displacement of the focal point increases as the exposure proceeds, as shown in Fig. 1. When the exposure starts at a time t_0, the displacement increases with time and a stationary state is reached at a time t_1. Then, if the exposure terminates at a time t_2, the displacement decreases with time and becomes zero at a time t_3. The displacement of the focal point would not be a trouble so far as its amount is small enough. But, if the displacement surpasses the range of a depth of focus, it becomes a great problem.

(2) Shift of an image magnification of a projection lens:

The shift also occurs since the projection lens absorbs part of exposure light. As shown in Fig. 2, the displacement of the image magnification increases as the exposure proceeds. When the exposure starts at a time t_0, the displacement increases with time and a stationary state is reached at a time t_1. Then, if the exposure terminates at a time t_2, the displacement decreases with time and becomes zero at a time t_3. Displacement of the image magnification would directly influence an arranging accuracy of circuit patterns on the wafer, and this becomes a great problem when a refined circuit pattern is depicted on the wafer.

(3) Symmetrical distortion of a projection lens:

The distortion also occurs since the projection lens absorbs part of exposure light. The distortion could not be removed even if a projection lens of high performance is used which is designed to have no distortion at a stage of production thereof.

(4) Curvature of field of a projection lens:

The curvature of field also occurs since the projection lens absorbs part of exposure light. When the a wafer whose exposure area is enlarged to 20 mm× 20 mm, it is difficult to maintain a best focused state over an entire exposure area of the wafer due to the shift of curvature of field of the projection lens. Thus, a limit to a higher resolution occurs.

In a conventional projection exposure apparatus, the problems of (1) and (2) discussed above are solved by the following measures (a) and (b), and even if a focal point and an image magification of the projection lens are greatly varied, these variations are corrected so that a circuit pattem on a reticle can be transferred on a silicon wafer under permissible conditions. But, the above-noted problems (3) and (4) are not yet be solved.

(a) Measures to a shift of a focal point:

A stage on which a silicon wafer is mounted is moved in a direction of an optical axis of the projection lens. Thus, a distance between the silicon wafer and the projection lens is adjusted according to the displacement of the focal point of the projection lens.

(b) Measures to a shift of an image magnification:

A sealed space is provided in a given space between lenses consisting of a projection lens. The air pressure in the sealed space is adjusted according to the shift of the image magnification of the projection lens (see Japanese Patent Laid-Open No. 60-078454). Or, a distance between the reticle and the projection lens, or distances between respective lenses consisting of

the projection lens is adjusted according to the shift of the image magnification.

Therefore, in order to obtain a still further higher resolution in the conventional projection exposure apparatus, the problem about the symmetrical distortion of the projection lens as shown in Figs. 3A and 3B or the curvature of field thereof must be solved.

In more detail, in a reduced projection exposure apparatus wherein only the correction of a shift of a focal point of a projection lens and the correction of a correction of an image magnification are performed. There is a problem that a pattern image 201 formed on a wafer as shown by a solid line in Fig. 3A has a barrel type distortion in which four sides of a square are curved outwardly, compared with a regular pattern image 200 as shown by dotted lines, when the projection lens involves a barrel type distortion which is a kind of symmetrical distortions. On the other hand, there is a problem that a pattern image 202 formed on a wafer as shown by a solid line in Fig. 3B has a pin-cushion type distortion in which four sides of a square are curved inwardly, compared with a regular pattern image 200 as shown by dotted lines, when the projection lens involves a pin-cushion type distortion which is also a kind of symmetrical distortions.

When the projection lens involves a curvature of field which ia a kind of aberrations, the pattern image partially shifts in a direction perpendicular to an exposure surface from a regular pattern image.

A concern of this invention is to provide a projection exposure apparatus and a method in which influences of a partial shift of a pattern image on a substrate in at least one of directions along an exposure surface from a regular pattern image are reduced or eliminated to obtain a higher resolution.

Japanese Patent Abstract No. JP-A-2072634 discloses a method or apparatus for projecting an image in which the object surface is physically distorted to compensate for optical distortions of the projection system.

German Patent Specification No. DE-A-1522285 is concerned with correcting field curvature. Accordingly this reference provides no teaching leading to the solution of the problem caused by non-uniformity of the magnification power of a projection system.

An embodiment of this invention provides a projection exposure apparatus in which influences of symmetrical distortion or of curvature of field of a projection lens are reduced or eliminated to obtain a higher resolution.

According to one aspect of the present invention there is provided projection apparatus as set out in claim 1.

According to another aspect of the present invention there is provided a projection method as set out in claim 7.

The present invention will be more readily understood in connection with the following detailed description of the accompanying drawings, in which:

Fig. 1 is a representation illustrating a displacement with time of a focal point of a projection lens in a projection exposure apparatus.

Fig. 2 is a representation illustrating a displacement with time of an image magnification of a projection lens in a projection exposure apparatus.

Fig. 3A is a plan view illustrating a deformed pattern image due to a barrel type distortion of a projection lens.

Fig. 3B is a plan view illustrating a deformed pattern image due to pin-cushion type distortion of a projection lens.

Fig. 4 is a schematic diagram of a first embodiment of a reduced projection exposure apparatus according to the present invention.

Fig. 5 is a plan view illustrating a method for fixing a reticle by driving devices in the first embodiment of the present invention.

Fig. 6 is a plan view illustrating a reticle and a circuit pattern deformed when expandable portions of driving devices are extended in the first embodiment of the present invention.

Fig. 7 is a plan view illustrating a reticle and a circuit pattern deformed when expandable portions of driving devices are shrinked in the first embodiment of the present invention.

Fig. 8 is a schematic diagram of a second embodiment of a reduced projection exposure apparatus according to the present invention.

Fig. 4 shows a first embodiment of a projection exposure apparatus according to the present invention. This figure is a schematic view of a reduced projection type exposure apparatus for producing a semiconductor integrated circuit.

In the first embodiment, ther are provided, as shown in Fig. 4, an illuminating device 1 for emitting an exposure light of ultraviolet light, a reticle 2 having theron a circuit pattern 26 and having a desired shape (herein, a square as shown in Fig, 5 for the convenience of explanation), a silicon wafer 4 on which a pattern image of a reduced image of the circuit pattern 26 is to be formed, a projection lens 3 for imaging the circuit pattern 26 onto the silicon wafer 4 at a predetermined reduction ratio, a stage 5 on which the silicon wafer 4 is mounted and which controls the position of the silicon wafer 4, a focal point controller 12 for controlling a correction of a shift of a focal point of the projection lens 3, and an image magnification controller 13 for controlling a correction of a shift of an image magnification of the projection lens 3.

The illuminating device 1 includes a light source for radiating light such as ultraviolet light, a shutter device, a condensor lens and the like. The reticle 2 and the silicon wafer 4 are disposed opposing each other in an optical axis of the exposure light radiated from the illuminating device 1. The projection lens 3 is disposed between the reticle 2 and the silicon wafer 4. The focal point controller 12 moves the stage 5 up and down according to a control signal for correcting the position a focal point output from an arithmetic or processing unit 11 explained below. The image magnification controller

13 adjusts an air pressure in a sealed space provided in the projection lens 3 according to a control signal for correcting the image magnification output from the arithmetic unit 11.

In the first embodiment, there are further provided four driving devices 20-23 which are respectively means for deforming the reticle 2 in its surface direction, the arithmetic unit 11 which is means for calculating deviations between an original geometric shape (square) of the circuit pattern 26 formed on the reticle 2 and a geometric shape of a pattern image formed on the silicon wafer 4, and a distortion controller 14 which is means for controlling four driving devices 20-23 to coincide the geometric shape of the pattern image with the original geometric shape of the circuit pattern 26.

The arithmetic unit 11 includes a memory 10 for storing first data which is obtained beforehand by measuring a relationship between a symmetrical distortion of the projection lens 3 and time lapsed from a start of exposure, and a timer 15 for measuring the time from the start of exposure. The first data is read out from the memory 10 by inputting into the memory 10 the time measured by the timer 15. Then, the unit 11 obtaines the deviation based on the thus read first data, and generates the control signal for correcting the distortion.

Further, the memory 10 stores second and third data which are obtained beforehand by measuring displacements with time of the focal point and the image magnification of the projection lens 3 (see Figs. 1 and 2). The arithmetic unit 11 reads the second and third data by inputting into the memory 10 the time from the start of exposure measured by the timer 15. The unit 11 generates the control signal for correcting a focal point and the control signal for correcting an image magnification based on the thus read second and third data.

As shown in Fig. 5, four driving devices 20-23 are fixed to central portions of four sides of the reticle 2. The driving devices 20-23 are respectively composed of expansible portions 20a-23a whose expansion or shrinkage amounts are controlled by the control signals from the distortion controller 14 and which consist of piezoelectric elements, and stationary portions 20b-23b for fixing the reticle 2. One end of each expansible portion 20a-23a is fixed to a support frame 25 made of material of high regidity. The other end of each expansible portion 20a-23a is fixed to each stationary portion 20b-23b.

Therefore, as shown in Figs. 6 and 7, the reticle 2 is deformed inward in its surface direction by outputting the control signal from the distortion controller 14 to the expansible portion 20a-23a of each driving device 20-23. If the expansible portions 20a-23a are extended by an equal length according to the control signal, the reticle 2 is deformed to a pin-cushion shape as shown in Fig. 6. On the other hand, if the expansible portions 20a-23a are shrinked by an equal length according to the control signal. the reticle 2 is deformed to a barrel shape as shown in Fig. 7. At this time, the square circuit pattern 26 on the reticle 2 shown by hatchings in Fig. 5 is also deformed inwardly or outwardly according to the deformation of the reticle 2 as shown in Figs. 6 and 7.

Next, the operation of the first embodiment will be explained.

The exposure light (ultraviolet light) radiated from the illuminating device 1 illuminates the reticle 2 uniformly, and the exposure light applied to a portion on which the circuit pattern 26 is formed transmits through the reticle 2, while a remaining exposure light is reflected by the reticle 2. The transmitted exposure light is reduction-projected by the projection lens 3 at a predetermined reduction ratio (normally 1/5 or 1/10). On the exposure surface of the silicon wafer 4, resist which is to be chemically changed by the exposure light is uniformly coated. Therefore, the resist on a portion on which the transmitted exposure light applied is subjected to chemical reaction, so that the circuit pattern 26 is transferred onto the silicon wafer 4. Thus, the pattern image which is reduced from the circuit pattern 26 at the predetermined reduction ratio, is formed on the wafer 4.

In the reduced projection exposure apparatus of the first embodiment, the displacement of the focal point, the shift of the image magnification and the symmetrical distortion of the projection lens 3 arise. The degradation of resolution due to those factors are prevented in this embodiment in the following manner.

(1) Prevention of adverse influences due to displacement of a focal point:

When the exposure is started, the arithmetic unit 11 inputs time elapsed from the start of exposure measured by the timer 15 into the memory 10 and the second data stored in the memory 10 (the shift with time from the start of exposure of the focal point of the projection lens 3 obtained by measurement) is read. Then, the focal point correction control signal produced based on the thus read second data is output to the focal point control device 12. The focal point control device 12 moves the stage 5 up and down based on the focal point correction control signal, and adjusts the distance between the projection lens 3 and the stage 5 according to the shift of the focal point of the projection lens 3.

(2) Prevention of adverse influences due to shift of an image magnification:

When the exposure is started, the arithmetic unit 11 inputs time elapsed from the start of exposure measured by the timer 15 into the memory 10 and the third data stored in the memory 10 (the shift with time from the start of exposure of the image magnification of the projection lens 3 obtained by measurement) is read. Then, the image magnification correction control signal produced based on the thus read third data is output to the image magnification control device 13. The image magnification control device 13 changes the pressure of air in the sealed space provided in the projection lens

3 based on the image magnification correction control signal, and adjusts the pressure of air in the sealed space according to the shift of the image magnification of the projection lens 3.

(3) Prevention of adverse influences due to a symmetrical distortion:

When the exposure is started, the arithmetic unit 11 inputs time elapsed from the start of exposure measured by the timer 15 into the memory 10 and the first data stored in the memory 10 (the relationship between time from the start of exposure and the symmetrical distortion of the projection lens 3 obtained by measurement) is read. Then, the distortion correction control signal produced based on the thus read first data is output to the distortion control device 14. The distortion control device 14 outputs control signals to the respective driving devices 20-23 according to the distortion correction control signal. and deforms the reticle 2 in its surface direction according to the symmetrical distortion of the projection lens 3. More in particular, the arithmetic unit 11 calculates from the first data read out from the memory 10 the deviation between the original geometric shape (square) of the circuit pattern 26 formed on the reticle 2 and the geometric shape of the pattern image formed on the silicon wafer 4. If a barrel type distortion of the pattern image due to the barrel type distortion of the projection lens 3 (see Fig. 3A) is confirmed, the arithmetic unit 11 produces a distortion correction control signal for instructing that the reticle 2 be made pin-cushion shaped as shown in Fig. 6. The distortion control device 14 which receives the thus produced distortion correction control signal outputs control signals to the respective driving devices 20-23 for extending the expansible portions 20a-23a by predetermined amounts. On the other hand. if the deviation is calculated based on the first data read from the memory 10 and a pin-cushion type distortion of the pattern image due to the reel type distortion of the projection lens 3 (see Fig. 3B) is confirmed, the arithmetic unit 11 produces a distortion correction control signal for instructing that the reticle 2 be made barrel-shaped as shown in Fig. 7. The distortion control device 14 which receives the thus produced distortion correction control signal outputs control signals to the respective driving devices 20-23 for shrinking the expansible portions 20a-23a by predetermined amounts.

As a result, in this embodiment, even when the barrel-type or pin-cushion type distortion of the pattern image formed on the silicon wafer 4 is created due to the symmetrical distortion of the projection lens 3, the reticle 2 can be deformed in its surface direction and the circuit pattern 26 formed on the reticle 2 can be deformed so that the distortion of the pattern image is eliminated. Thus, adverse influences due to the distortion of the pattern image formed on the silicon wafer 4 can be prevented.

Therefore, in the reduced projection exposure apparatus of the first embodiment, degradation of resolution due to a symmetrical distortion of the projection lens 3 as well as that due to shifts of a focal point of the projection lens 3 and an image magnification thereof can be prevented.

Fig. 8 shows a second embodiment of a projection exposure apparatus according to the present invention. This is a schematic view of a reduced projection type exposure apparatus for producing a semiconductor integrated circuit.

The second embodiment differs from the first embodiment in the following points. First, there is provided. as shown in Fig. 8. a temperature sensor 60 in a projection lens 33. An arithmetic unit 41 is connected to a memory 40 which stores first data obtained by measuring the relationship between a symmetrical distortion of the projection lens 33 and the temperature indicated by the sensor 60. The first data is read out by inputting the temperature indicated by the sensor 60 into the memory 40, and the arithmetic unit 44 calculates the abovementioned deviation based on the thus read first data to produce a distortion correction control signal.

Further, the memory 40 stores second and third data which are obtained by measuring a relationship between a shift of a focal point of the projection lens 33 and the temperature and that between a shift of an image magnification of the projection lens 3 and the temperature, respectively. The arithmetic unit 41 reads the second and third data by inputting the temperature indicated by the sensor 60. and produces focal point correction and image magnification correction control signals based on the thus read second and third data.

Also in the reduced projection exposure apparatus of the second embodiment, the displacement of the focal point. the shift of the image magnification and the symmetrical distortion of the projection lens 3 arise due to the absorption of part of the exposure light by the projection lens 33. The degradation of resolution due to those factors are prevented in this embodiment in the following manner.

(1) Prevention of adverse influences due to displacement of a focal point:

When the exposure is started, the arithmetic unit 41 takes in an output signal of the sensor 60 and inputs into the memory 40 the temperature of the projection lens 33 indicated by this output signal, and the second data stored in the memory 40 (the relationship between displacement of a focal point of the projection lens 33 and temperature indicated by the sensor 60 obtained by measurement) is read. Then, the focal point correction control signal produced based on the read second data is output to the focal point control device 42. The focal point control device 42 moves the stage 35 up and down according to the focal point correction control signal, and adjusts the distance between the projection lens 33 and

the stage 35 according to the shift of the focal point of the projection lens 33.

(2) Prevention of adverse influences due to shift of an image magnification:

When the exposure is started, the arithmetic unit 41 takes in an output signal of the sensor 60 and inputs into the memory 40 the temperature of the projection lens 33 indicated by this output signal, and the third data stored in the memory 40 (the relationship between temperature indicated by the sensor 60 and shift of an image magnification of the projection lens 33 obtained by measurement) is read. Then, the image magnification correction control signal produced based on the read third data is output to the image magnification control device 43. The image magnification control device 43 chages the pressure of air in the sealed space disposed in the projection lens 33 based on the image magnification correction control signal, and adjusts the pressure of air in the sealed space according to the shift of the image magnification of the projection lens 33.

(3) Prevention of adverse influences due to a symmetrical distortion:

When the exposure is started, the arithmetic unit 41 takes in an output signal of the sensor 60 and inputs into the memory 40 the temperature of the projection lens 33 indicated by this output signal, and the first data stored in the memory 40 (the relationship between temperature indicated by the sensor 60 and a symmetrical distortion of the projection lens 33 obtained by measurement) is read. Then, the distortion correction control signal produced based on the read first data is output to the distortion controller 44. The distortion control device 44 outputs control signals to respective driving devices 50-52 (one driving device is noy shown in Fig. 8) according to the distortion correction control signal, and deforms the reticle 32 in its surface direction according to the symmetrical distortion of the projection lens 33.

More in particular, the arithmetic unit 41 calculates from the first data read out from the memory 40 the deviation between the original geometric shape (square) of the circuit pattern formed on the reticle 32 and the geometric shape of the pattern image formed on the silicon wafer 34. If a barrel type distortion of the pattern image due to the barrel type distortion of the projection lens 33 (see Fig. 3A) is confirmed, the arithmetic unit 41 produces a distortion correction control signal for instructing that the reticle 32 be deformed into a pin-cushion shape as shown in Fig. 6. The distortion control device 44 which receives thus produced dirtortion correction control signal outputs control signals to respective driving devices 50-52 for extending the expansible portions by predetermined amounts. On the other hand, if the deviation is calculated based on the first data read from the memory 40 and a pin-cushion type distortion of the pattern image due to the reel type distortion of the projection lens 33 (see Fig. 3B) is confirmed, the arithmetic unit 41 produces a distortion correction control signal for instructing that the reticle 32 be deformed into a barrel shape as shown in Fig. 7. The distortion control device 44 which receives thus produced distortion correction control signal, outputs control signals to respective driving devices 50-52 for shrinking the expansible portions by predetermined amounts.

As a result, also in this embodiment, even when the barrel-type or pin-cushion type distortion of the pattern image formed on the silicon wafer 34 is created due to the symmetrical distortion of the projection lens 33, the reticle 32 can be deformed in its surface direction and the circuit pattern formed on the reticle 32 can be deformed so that the distortion of the pattern image is eliminated. Thus, the distortion of the pattern image formed on the silicon wafer 34 can be prevented.

The position of the sensor 60 is preferablly in the vicinity of the optical axis of an exposure light where influence of the increase of temperature due to exposure appears most greatly. However, since the sensor 60 directly blocks the exposure light and an optical problem occurs if the sensor 60 is disposed in the vicinity of the optical axis, actually places where the influence of the increase of temperature due to exposure appears ccmparatively greatly are selected in an experimental manner or other manners from peripheral portions of the projection lens 33 where the exposure light does not pass. Since the increase of temperature at thus selected position of the temperature sensor 60 one-to-one corresponds to each of shifts of a focal point and an image magnification of the projection lens 33 and symmetrical distortion, their relationships are beforehand measured and the abovementioned three data are stored in the memory 40.

In the above-discussed structure, there are provided four driving devices as means for deforming a reticle in its surface direction, and central portions of four sides of a reticle are held by respective driving devices, but the number of driving devices is not limited to four.

Further, there is no need to extend or shrink respective expansible portions by an equal length. They may be extended or shrinked by different lengths. This is effective where, for example, a rectangular reticle is used.

Although mechanical means is used in places where portions holding a reticle such as the driving devices shown in Fig. 5 are extended or shrinked, as means for deforming the reticle in its surface direction, other means may be used, for example, means for deforming a reticle into a desired shape by thermal expansion by controlling positions to which heat is given and its amount.

The present invention can be applied to any type of projection exposure apparatus in which a pattem formed on an original is imaged onto a substrate at a predetermined ratio to form a pattern image on a substrate using a projection lens disposed between the orig-

inal and the substrate.

While there have been shown and described what are considered preferred embodiments of the present invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the invention as defined by the following claims.

Claims

1. Projection apparatus comprising a projection system (3) for projecting an image of a pattern on an original (2) onto a substrate (4), and characterised in that the apparatus includes compensating means (20-23, 14) adapted to compensate for optical distortion in the projection system by physically distorting the original in a direction parallel to a surface of the original.

2. Apparatus according to claim 1, wherein the compensating means is adapted to physically distorte the original in two orthogonal directions parallel to a surface of the original.

3. Apparatus according to claim 1 or claim 2, in which the compensating means is adapted either to compress or to expand the original.

4. Apparatus according to any one of the preceding claims, wherein the compensating means comprise:

   movable first support means (20-23) for supporting the original;
   arithmetic means (11) for calculating deviations between the original geometric shape of the pattern on the original and the geometric shape of the image of the pattern formed by the projection system on the substrate; and
   control means (14) for controlling movement of said compensation means in response to a deviation calculated by said arithmetic means so that the geometric shape of the image of the pattern on the substrate is made to coincide with the original geometric shape of the pattern on the original.

5. Apparatus according to claim 4, and wherein said arithmetic means include a timer for measuring the time elapsed from the start of the projection of an image, a memory for storing data obtained by measuring the relationship between the optical distortion of the projection system and time elapsed from the start of the projection of an image, and means for calculating deviation in respect to measured time elapsed from the start of the projection of an image and the data stored in the memory.

6. Apparatus according to claim 4, wherein the arithmetic means comprises:

   a temperature sensor (60) for measuring the temperature of the projection system;
   a memory for storing data obtained by measuring the relationship between optical distortion of the projection system and the temperature of the projection system; and
   means for calculating the deviation from the measured temperature and the stored data.

7. A projection method comprising the steps of:
   projecting an image of a pattern on an original (2) onto a substrate (4) using a projection system;
   characterised by the step of:
   compensating for optical distortion in the projection system by physically distorting the original in a direction parallel to a surface of the original.

8. A projection method according to claim 7 wherein the original is physically distorted in two orthogonal directions parallel to a surface of the original.

9. A projection method according to claim 7 or claim 8 wherein the original is compressed or expanded.

10. A projection method according to any one of claims 7 to 9 including the steps of:

   calculating deviations between the original geometric shape of the pattern on the original and the geometric shape of the image of the pattern formed on the substrate; and
   controlling the distortion of the original in response to a calculated deviation so that the geometric shape of the image of the pattern on the substrate is made to coincide with the original geometric shape of the pattern on the original.

11. A projection method according to claim 10 wherein the deviations are calculated by measuring the time elapsed from the start of the projection of an image, and calculating deviations using the measured time elapsed from the start of the projection of an image and a measured relationship between the optical distortion of the projection system and time elapsed from the start of the projection of an image.

12. A projection method according to claim 10 wherein the deviations are calculated by measuring the temperature of the projection system, and calculating deviation using the measured temperature and a measured relationship between optical distortions of the projection system and the temperature of the projection system.

13. A method of manufacturing a semiconductor device comprising the projection method according to any one of claims 7 to 12 and including forming a semiconductor device from the substrate.

Patentansprüche

1. Projektionsvorrichtung, die ein Projektionssystem (3), um eine Abbildung einer Struktur an einem Original (2) auf ein Substrat (4) zu projizieren, umfaßt und dadurch gekennzeichnet ist, daß die Vorrichtung Kompensationseinrichtungen (20 - 23, 14) enthält, die dazu eingerichtet sind, eine optische Verzerrung in dem Projektionssystem durch körperliches Verzerren des Originals in einer Richtung parallel zu einer Oberfläche des Originals auszugleichen.

2. Vorrichtung nach Anspruch 1, in welcher die Kompensationseinrichtungen dazu eingerichtet sind, das Original körperlich in zwei orthogonalen Richtungen parallel zu einer Oberfläche des Originals zu verzerren.

3. Vorrichtung nach Anspruch 1 oder Anspruch 2, in welcher die Kompensationseinrichtungen dazu eingerichtet sind, das Original entweder zu komprimieren oder zu expandieren.

4. Vorrichtung nach einem der vorhergehenden Ansprüche, in welcher die Kompensationseinrichtungen umfassen:

- bewegbare erste Trageinrichtungen (20 - 23), um das Original zu lagern;
- Recheneinrichtungen (11), um Abweichungen zwischen der ursprünglichen geometrischen Gestalt der Struktur an dem Original und der geometrischen Gestalt der durch das Projektionssystem auf dem Substrat erzeugten Abbildung der Struktur zu berechnen; und
- Regeleinrichtungen (14), um eine Bewegung der genannten Kompensationseinrichtungen in Abhängigkeit von einer durch die erwähnten Recheneinrichtungen berechneten Abweichung zu steuern, so daß die geometrische Gestalt der Abbildung der Struktur auf dem Substrat zur Übereinstimmung mit der ursprünglichen geometrischen Gestalt der Struktur an dem Original gebracht wird.

5. Vorrichtung nach Anspruch 4, in welcher die erwähnten Recheneinrichtungen einen Zeitgeber, um die vom Beginn der Projektion einer Abbildung an verstrichene Zeit zu messen, einen Speicher, um durch Messen der Beziehung zwischen der optischen Verzerrung des Projektionssystems sowie der vom Beginn der Projektion einer Abbildung an verstrichenen Zeit erhaltene Daten zu speichern, und Einrichtungen, um eine Abweichung in bezug auf eine gemessene, vom Beginn der Projektion einer Abbildung an verstrichene Zeit und den in den Speicher gespeicherten Daten zu berechnen, enthalten.

6. Vorrichtung nach Anspruch 4, in welcher die Recheneinrichtungen umfassen:

- einen Temperaturfühler (60), um die Temperatur des Projektionssystems zu messen;
- einen Speicher, um durch Messen der Beziehung zwischen der optischen Verzerrung des Projektionssystems sowie der Temperatur des Projektionssystems erhaltene Daten zu speichern; und
- Einrichtungen, um die Abweichung von der gemessenen Temperatur und den gespeicherten Daten zu berechnen.

7. Ein Projektionsverfahren, das die Schritte umfaßt des:

- Projizierens einer Abbildung einer Struktur an einem Original (2) auf ein Substrat (4) unter Verwendung eines Projektionssystems;
- gekennzeichnet durch den Schritt des:
- Ausgleichens einer optischen Verzerrung in dem Projektionssystem durch körperliches Verzerren des Originals in einer Richtung parallel zu einer Oberfläche des Originals.

8. Ein Projektionsverfahren nach Anspruch 7, in welchem das Original körperlich in zwei orthogonalen Richtungen parallel zu einer Oberfläche des Originals verzerrt wird.

9. Ein Projektionsverfahren nach Anspruch 7 oder Anspruch 8, in welchem das Original komprimiert oder expandiert wird.

10. Ein Projektionsverfahren nach einem der Ansprüche 7 bis 9, das die Schritte umfaßt des:

- Berechnens von Abweichungen zwischen der ursprünglichen geometrischen Gestalt der Struktur an dem Original sowie der geometrischen Gestalt der auf dem Substrat erzeugten Abbildung der Struktur; und
- Regelns der Verzerrung des Originals in Abhängigkeit von einer berechneten Abweichung, so daß die geometrische Gestalt der Abbildung der Struktur auf dem Substrat zur Übereinstimmung mit der ursprünglichen Gestalt der Struktur an dem Original gebracht wird.

11. Ein Projektionsverfahren nach Anspruch 10, in welchem die Abweichungen berechnet werden, indem die vom Beginn der Projektion einer Abbildung an verstrichene Zeit gemessen wird und Abweichungen unter Verwendung der vom Beginn der Projektion einer Abbildung an verstrichenen Zeit sowie einer gemessenen Beziehung zwischen der optischen Verzerrung des Projektionssystems und der vom Beginn der Projektion einer Abbildung an verstrichenen Zeit berechnet werden.

12. Ein Projektionsverfahren nacn Anspruch 10, in welchem die Abweichungen berechnet werden, indem die Temperatur des Projektionssystems gemessen sowie eine Abweichung unter Verwendung der gemessenen Temperatur und einer gemessenen Beziehung zwischen optischen Verzerrungen des Projektionssystems sowie der Temperatur des Projektionssystems berechnet werden.

13. Ein Verfahren zur Herstellung eines Halbleiter-Bauelements, das das Projektionsverfahren nach einem der Ansprüche 7 bis 12 umfaßt und die Erzeugung eines Halbleiter-Bauelements von dem Substrat einschließt.

Revendications

1. Appareil de projection comprenant un système de projection (3) pour projeter, sur un substrat (4), une image d'un motif situé sur un original (2), et caractérisé en ce que l'appareil comprend un moyen de compensation (20 à 23, 14) apte à compenser la distorsion optique dans le système de projection en déformant physiquement l'original dans une direction parallèle à la surface de l'original.

2. Appareil selon la revendication 1, dans lequel le moyen de compensation est apte à déformer physiquement l'original dans deux directions orthogonales parallèles à la surface de l'original.

3. Appareil selon la revendication 1 ou la revendication 2, dans lequel le moyen de compensation est apte soit à comprimer soit à dilater l'original.

4. Appareil selon l'une quelconque des revendications précédentes, dans lequel le moyen de compensation comprend :

   un premier moyen formant support mobile (20 à 23) pour supporter l'original ;
   un moyen arithmétique (11) pour calculer des écarts entre la forme géométrique d'origine du motif sur l'original et la forme géométrique de l'image du motif formé par le système de projection sur le substrat ; et
   un moyen de commande (14) pour commander le déplacement dudit moyen de compensation en réponse à l'écart calculé par ledit moyen arithmétique de façon à faire coïncider la forme géométrique de l'image du motif sur le substrat avec la forme géométrique d'origine du motif sur l'original.

5. Appareil selon la revendication 4, et dans lequel ledit moyen arithmétique comprend une horloge pour mesurer le temps écoulé depuis le début de la projection d'une image, une mémoire pour mémoriser des données obtenues en mesurant la relation entre la distorsion optique du système de projection et le temps écoulé depuis le début de la projection d'une image, et un moyen pour calculer l'écart en fonction du temps mesuré écoulé depuis le début de la projection d'une image et des données mémorisées dans la mémoire.

6. Appareil selon la revendication 4, dans lequel le moyen arithmétique comprend :

   un capteur de température (60) pour mesurer la température du système de projection ;
   une mémoire pour mémoriser des données obtenues en mesurant la relation entre la distorsion optique du système de projection et la température du système de projection ; et
   un moyen pour calculer l'écart à partir de la température mesurée et des données mémorisées.

7. Procédé de projection comprenant les étapes :
   de projection, sur un substrat (4), d'une image d'un motif situé sur un original (2), en utilisant un système de projection ;
   caractérisé par l'étape :
   de compensation de la distorsion optique dans le système de projection en déformant physiquement l'original dans une direction parallèle à la surface de l'original.

8. Procédé de projection selon la revendication 7, dans lequel on déforme physiquement l'original dans deux directions orthogonales parallèles à la surface de l'original.

9. Procédé de projection selon la revendication 7 ou la revendication 8, dans lequel on comprime ou dilate l'original.

10. Procédé de projection selon l'une quelconque des revendications 7 à 9, incluant les étapes :

   de calcul d'écarts entre la forme géométrique d'origine du motif sur l'original et la forme géométrique de l'image du motif formé sur le

substrat ; et
de commande de la déformation de l'original en réponse à un écart calculé, de façon à faire coïncider la forme géométrique de l'image du motif sur le substrat avec la forme géométrique d'origine du motif sur l'original.

11. Procédé de projection selon la revendication 10, dans lequel on calcule les écarts en mesurant le temps écoulé depuis le début de la projection d'une image, et en calculant les écarts en utilisant le temps mesuré écoulé depuis le début de la projection d'une image et une relation mesurée entre la distorsion optique du système de projection et le temps écoulé depuis le début de la projection d'une image.

12. Procédé de projection selon la revendication 10, dans lequel on calcule les écarts en mesurant la température du système de projection, et en calculant l'écart en utilisant la température mesurée et une relation mesurée entre les déformations optiques du système de projection et la température du système de projection.

13. Procédé de fabrication d'un dispositif à semi-conducteur comprenant le procédé de projection selon l'une quelconque des revendications 7 à 12 et incluant la formation d'un dispositif à semi-conducteur à partir du substrat.

FIG. 1

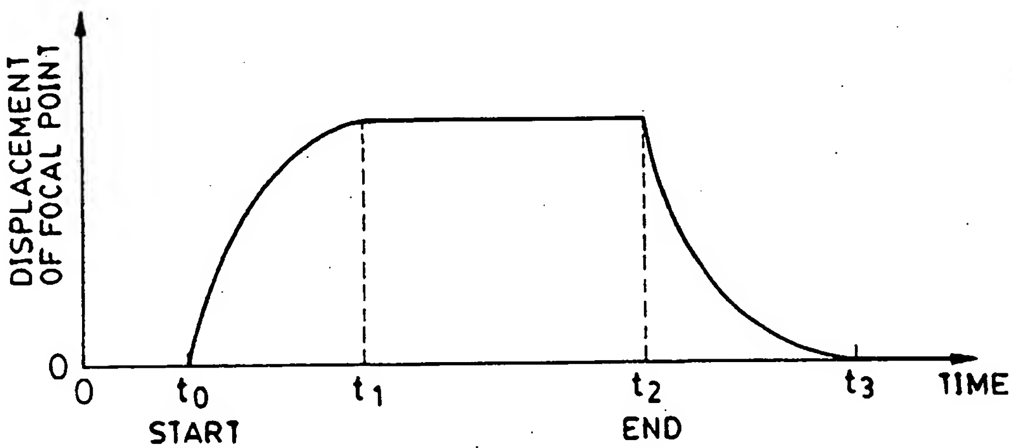

DISPLACEMENT
OF FOCAL POINT
0
0
t_0
START
t_1
t_2
END
t_3
TIME

FIG. 2

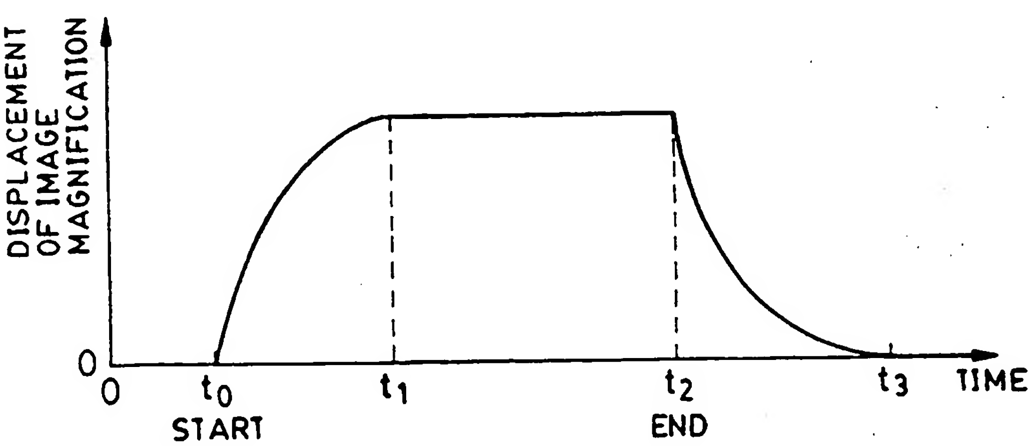

DISPLACEMENT
OF IMAGE
MAGNIFICATION
0
0
t_0
START
t_1
t_2
END
t_3
TIME

FIG. 3A

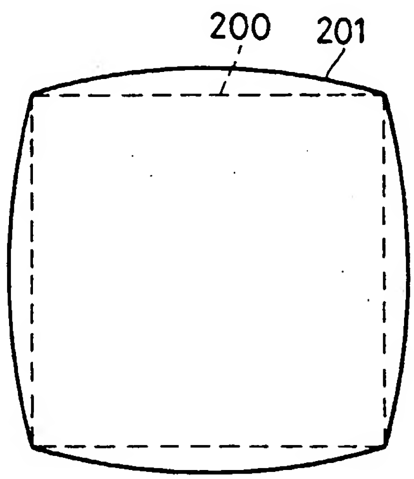


FIG. 3B

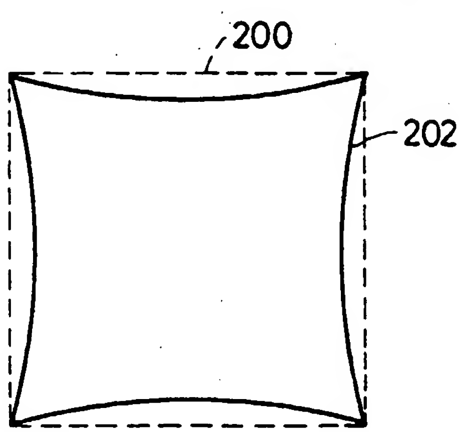


FIG. 4

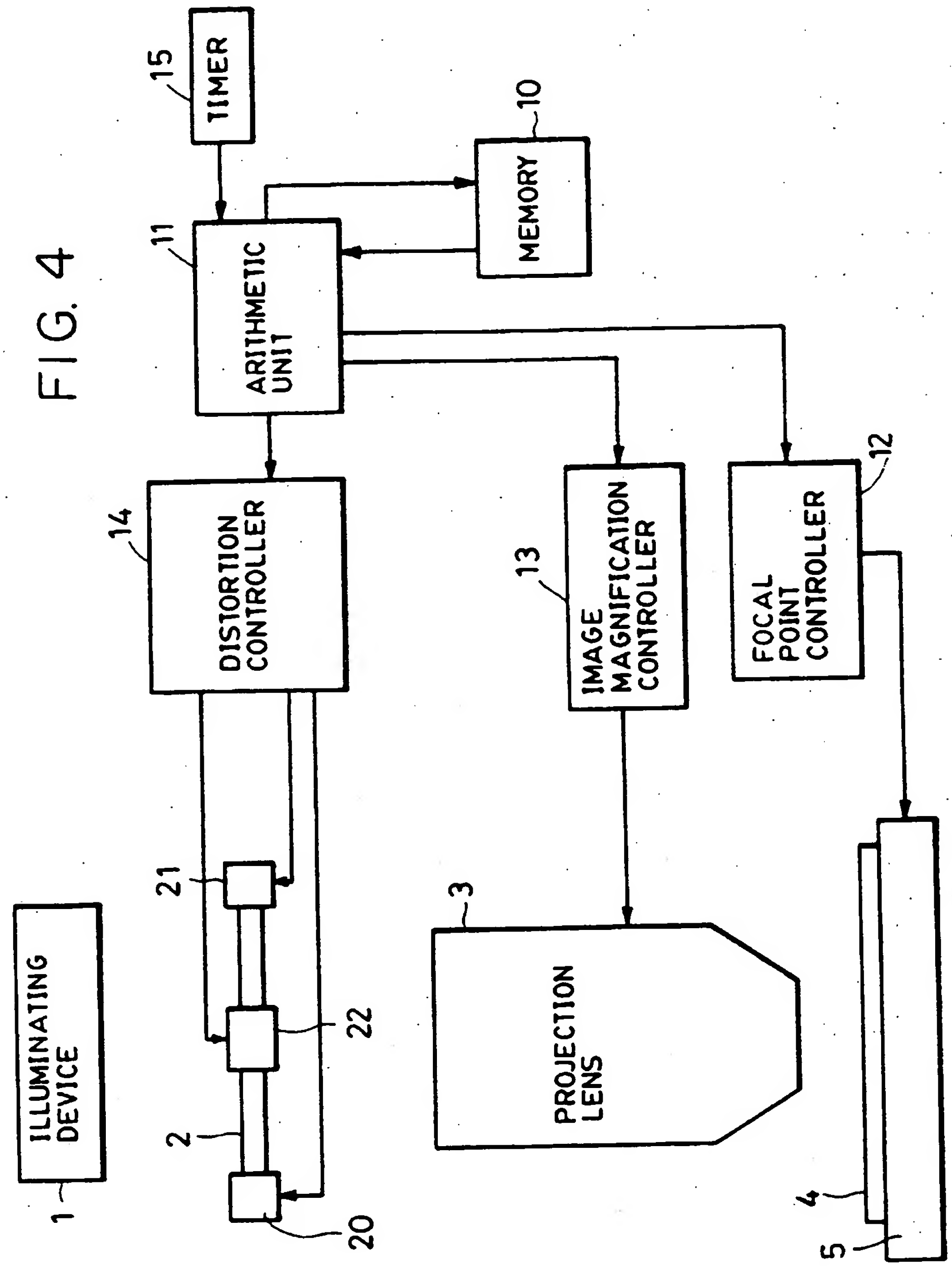

TIMER
15
MEMORY
10
ARITHMETIC UNIT
11
DISTORTION CONTROLLER
14
IMAGE MAGNIFICATION CONTROLLER
13
FOCAL POINT CONTROLLER
12
ILLUMINATING DEVICE
1
21
22
2
20
PROJECTION LENS
3
4
5

FIG. 5

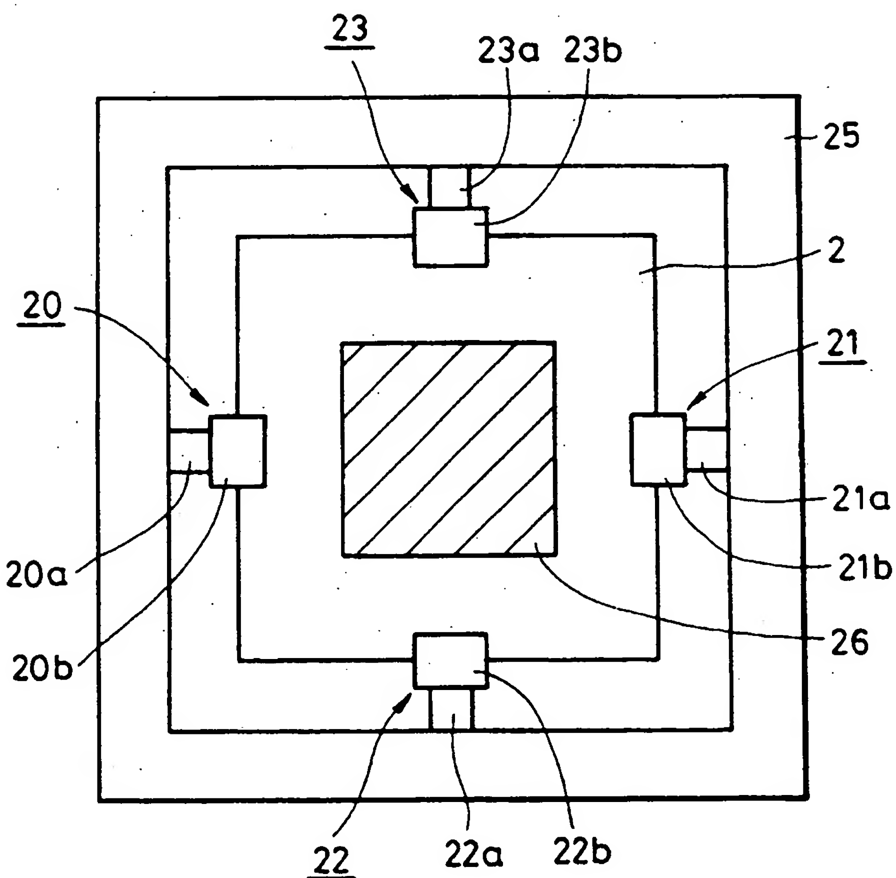


FIG. 6

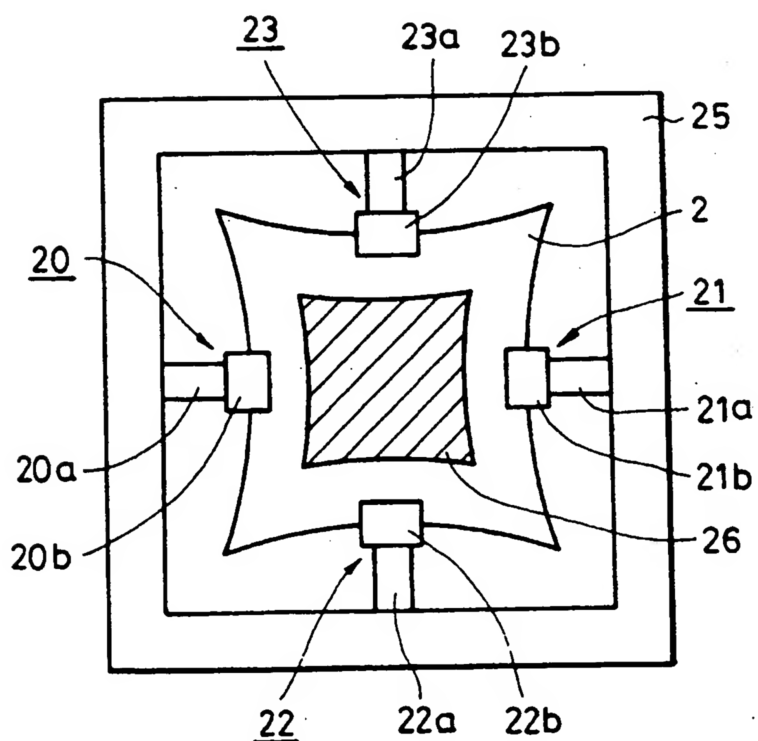
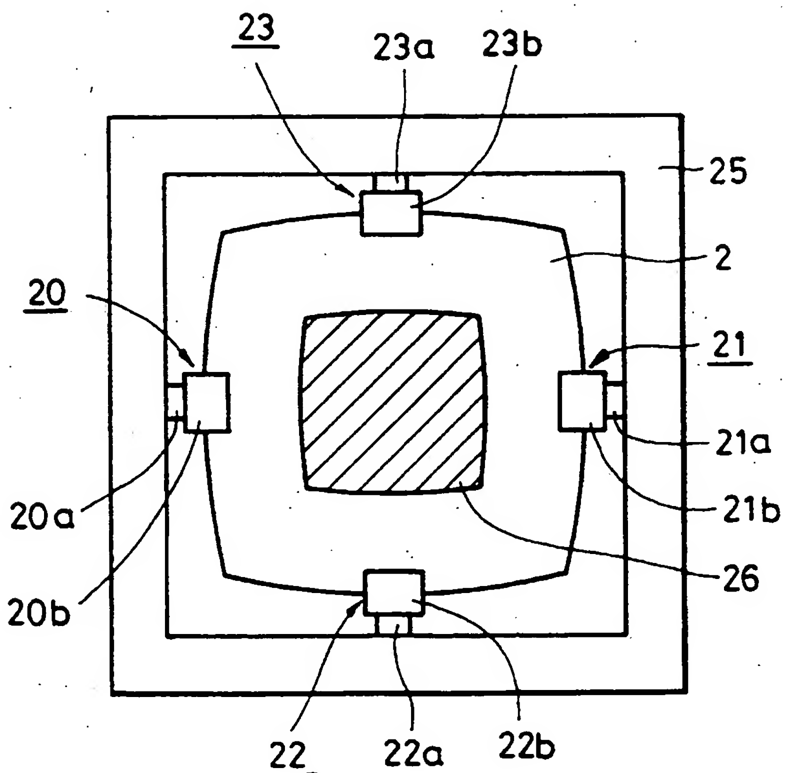


FIG. 7



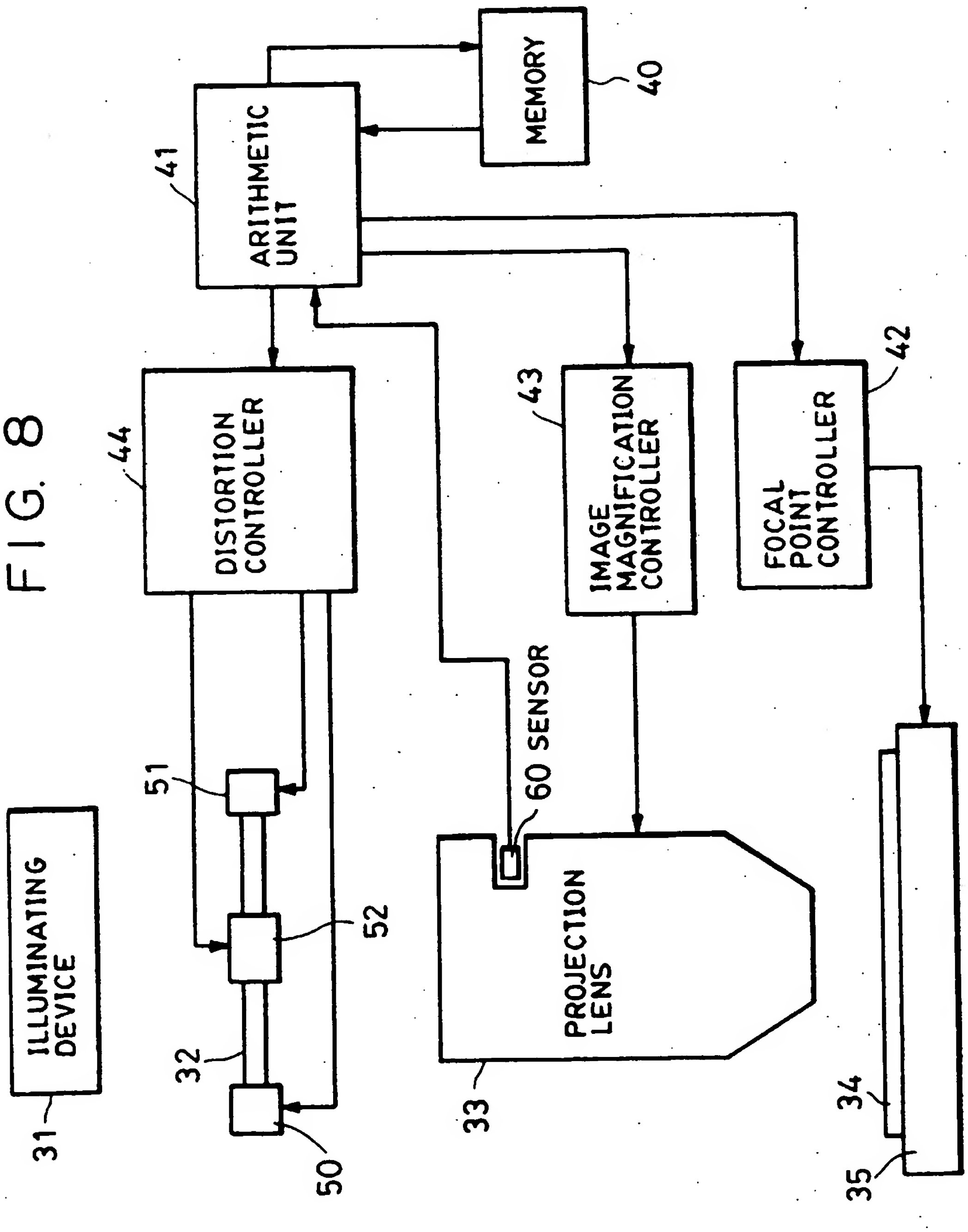

MEMORY
40
41
ARITHMETIC UNIT
44
DISTORTION CONTROLLER
43
IMAGE MAGNIFICATION CONTROLLER
42
FOCAL POINT CONTROLLER
60 SENSOR
51
52
32
50
31
ILLUMINATING DEVICE
PROJECTION LENS
33
34
35

FIG. 8

FIG. 9

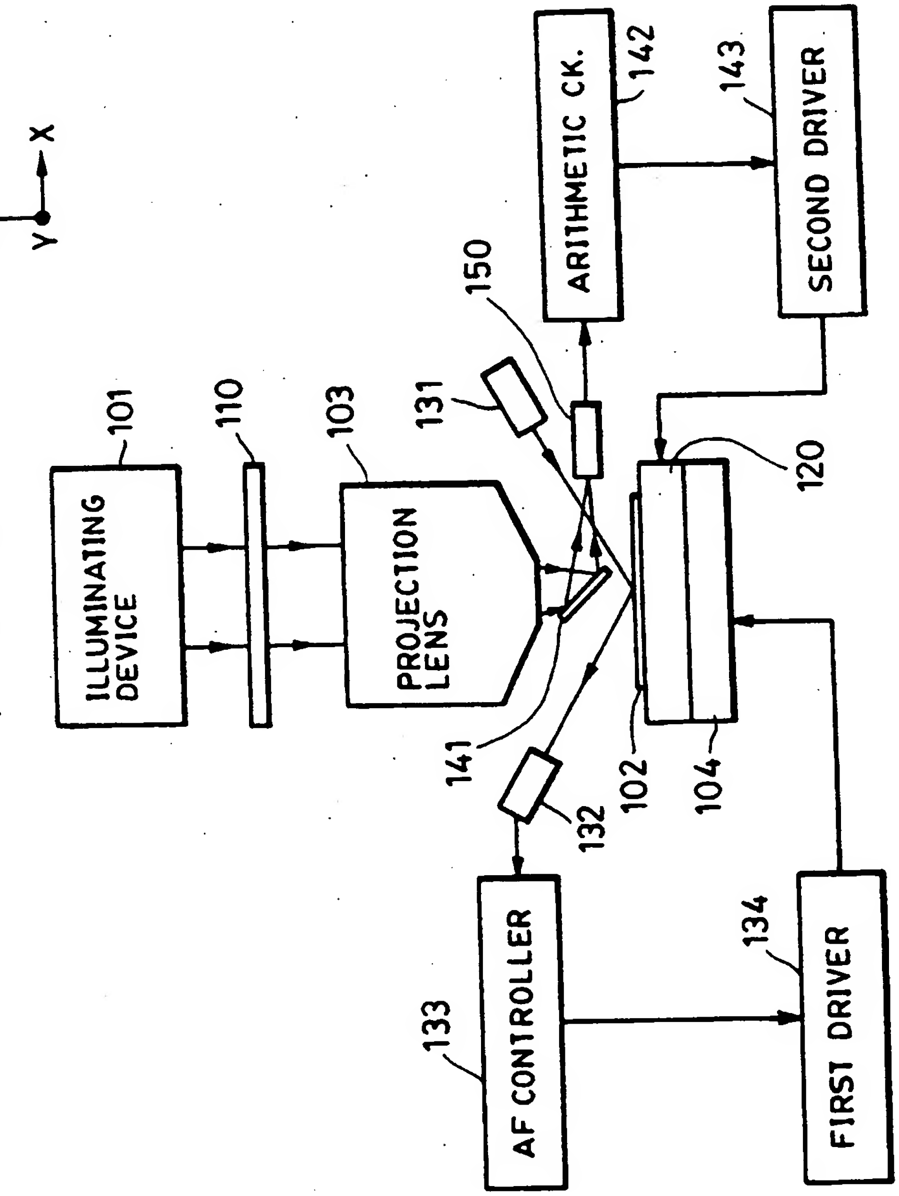

ILLUMINATING DEVICE
101
110
PROJECTION LENS
103
131
150
141
132
102
104
120
ARITHMETIC CK.
142
143
SECOND DRIVER
AF CONTROLLER
133
134
FIRST DRIVER
Z
Y
X

FIG. 10

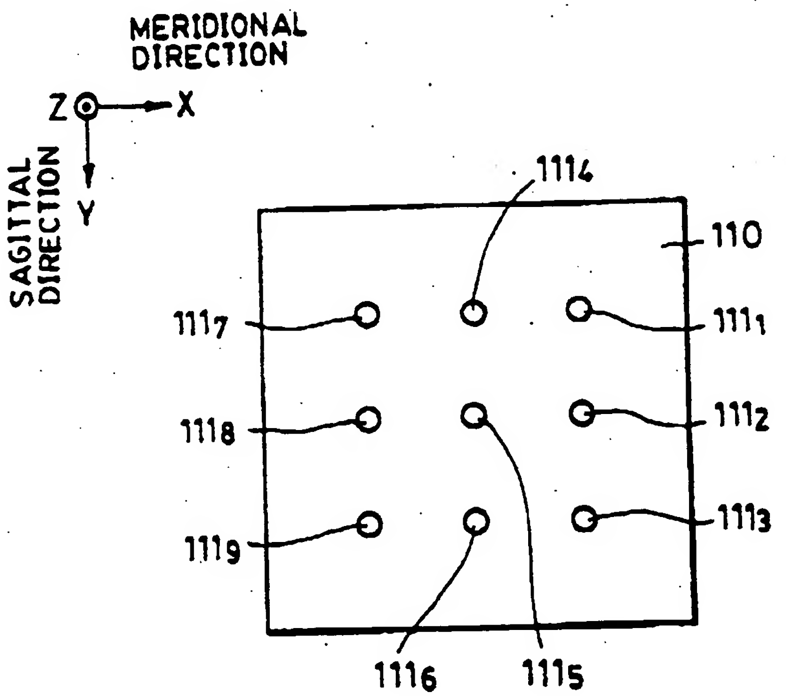

MERIDIONAL DIRECTION
Z
X
Y
SAGITTAL DIRECTION
111_4
110
111_7
111_1
111_8
111_2
111_9
111_3
111_6
111_5

FIG. 11

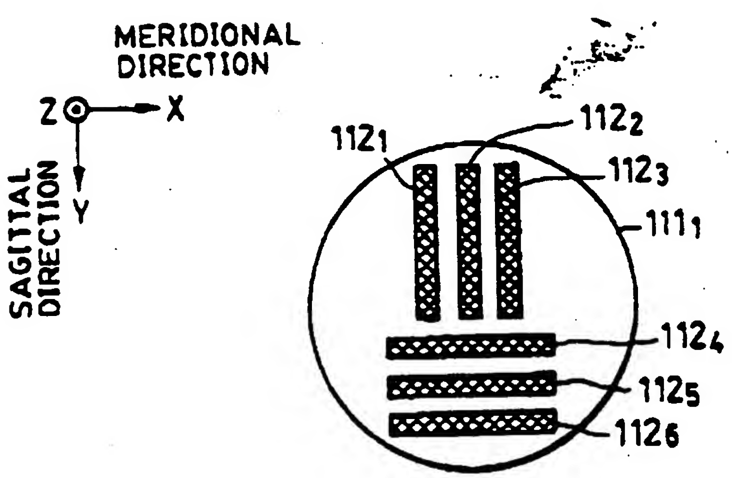

MERIDIONAL DIRECTION
Z
X
Y
SAGITTAL DIRECTION
112_1
112_2
112_3
111_1
112_4
112_5
112_6

FIG. 12A

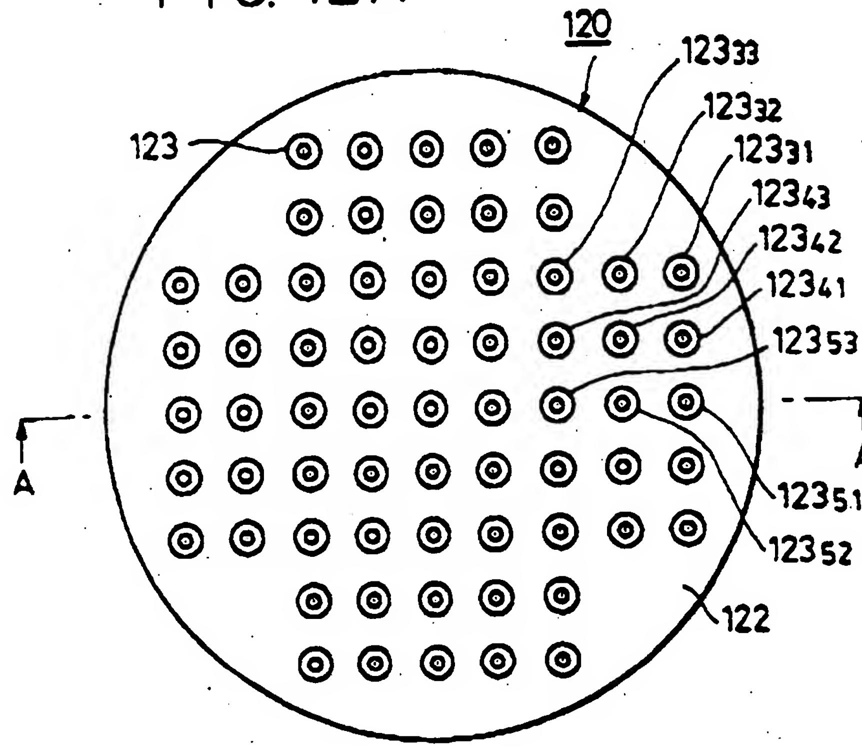


FIG. 12B

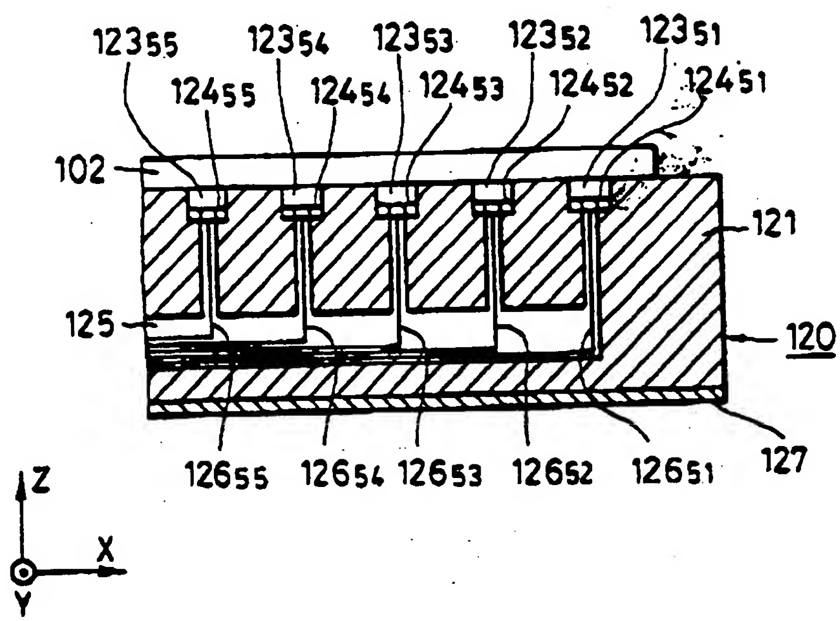


FIG. 13

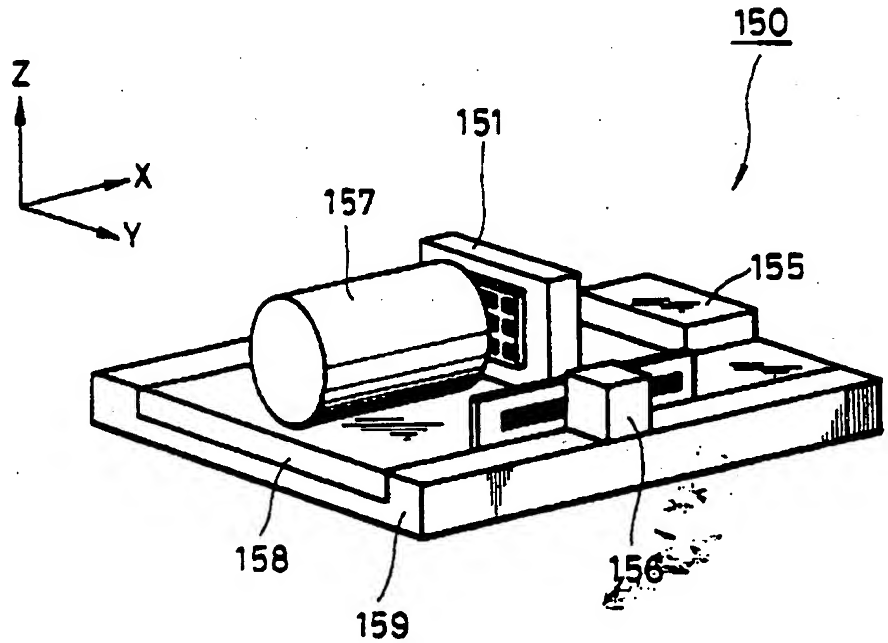


FIG. 14

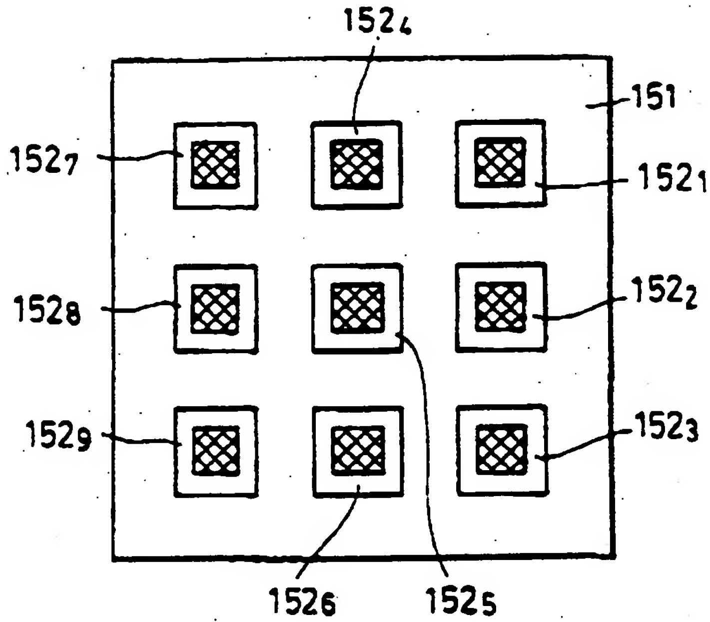

152_4
151
152_7
152_1
152_8
152_2
152_9
152_3
152_6
152_5

FIG. 15

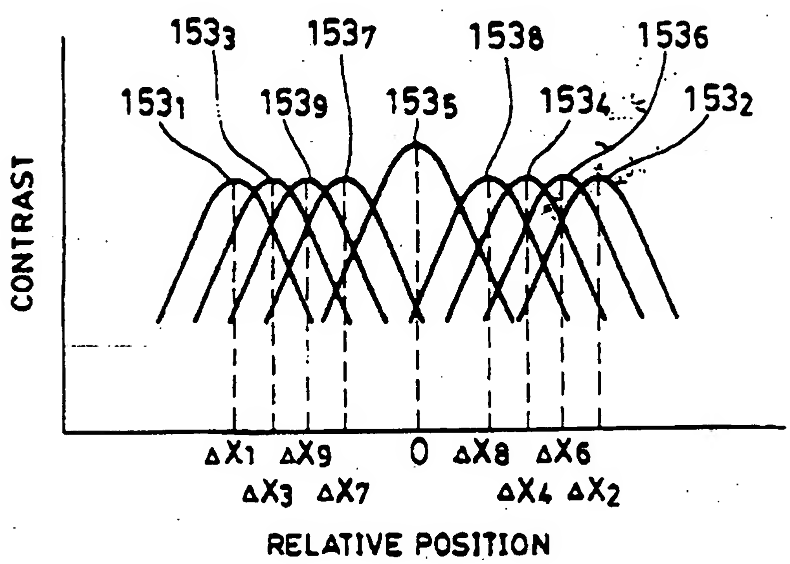

153_3
153_7
153_8
153_6
153_1
153_9
153_5
153_4
153_2
CONTRAST
ΔX_1 ΔX_9 0 ΔX_8 ΔX_6
ΔX_3 ΔX_7 ΔX_4 ΔX_2
RELATIVE POSITION

FIG. 16

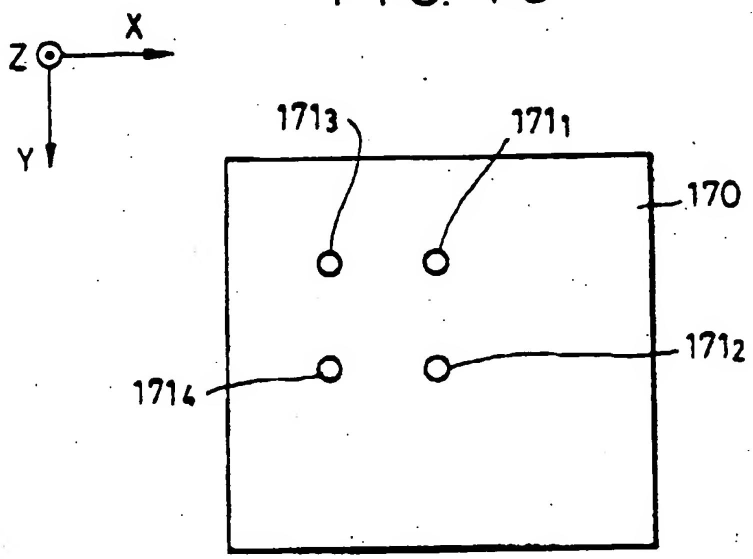


FIG. 17

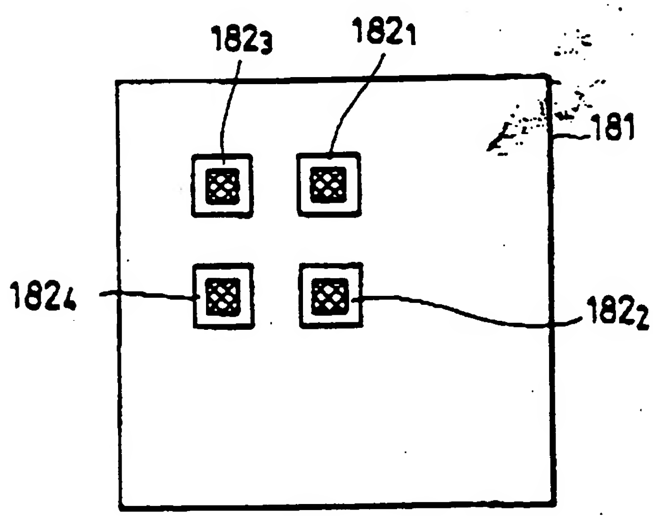


FIG. 18A

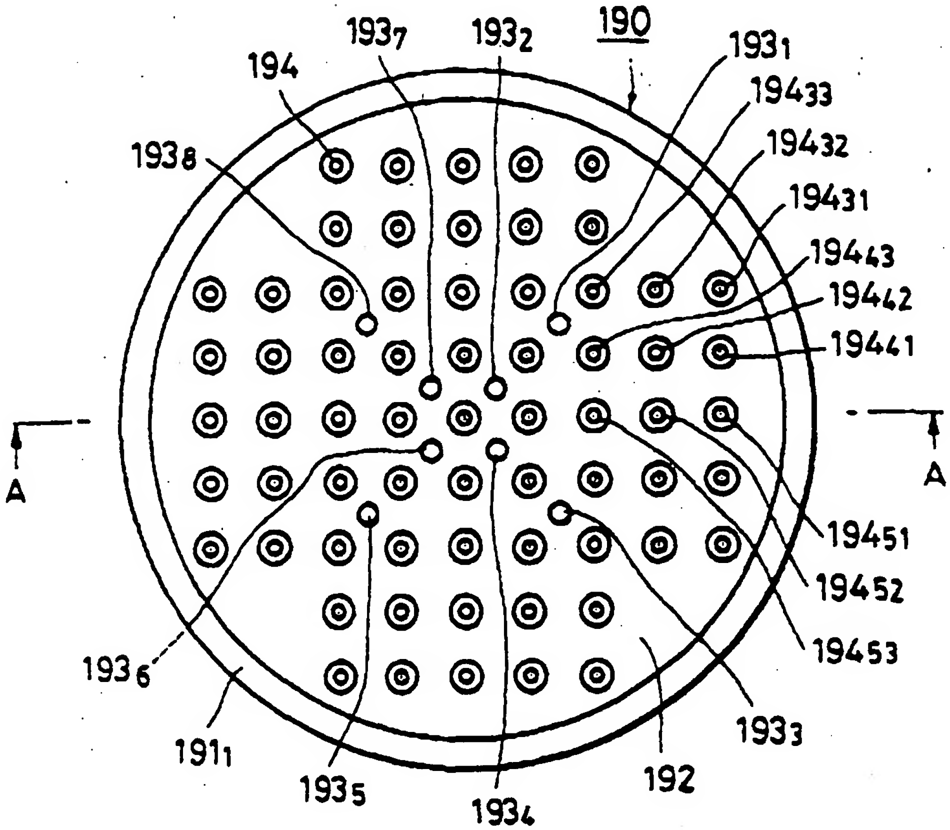


FIG. 18B